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The Future of Genomics in Farm Animals and the ERA

The Farm Animal Industrial Platform (*FAIP*), forum of European farm animal breeding and reproduction organisations (both industries and umbrellas of SMEs), welcomes the initiative of the European Research Area

- to reinforce links with national efforts and networking, and
- to use among others large and long standing projects to strengthen and implement the role of genomics.

Genomics and bio-informatics in farm animals will lead to new and more sustainable farm animal breeding concepts. European livestock breeding – now leading at the global level - needs these concepts in order

- to stay competitive at the world level, and
- to decide how European farm animals will look like.

The use of GMOs in animal production is economically not feasible and not accepted by society. Therefore, the main implementation of genomics in livestock will be the use of genetic markers in selection (Marker Assisted Selection). Also the better understanding of biology will lead to new breeding goals.

Genomics and bio-informatics need to be supported internationally, because the concepts are too expensive for single member states, let alone for SMEs. Access of breeders and genetic resources to the use of genome information needs careful attention. Research efforts are necessary on finemapping, sequencing, functional genomics, bio-informatics and, very important, implementation of research into breeding practice.

The emphasis should be on

- European wide integration of national efforts, including industries and SMEs (or networks representing them),
- improved links between human, farm animal and plant genomics and bio-informatics,
- special networks for the four main farm animal species (pigs, cattle, chicken, fish),
- special projects for small research groups and industries to connect within larger networks,
- special attention for implementation of research results into practical breeding,
- exchange of scientists, and
- for genetic resources: programmes on semen, egg and embryo preservation and use.

A continuous dialogue with society while developing sustainable future breeding and reproduction strategies is important.

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Summary

Genomics offer possibilities for sustainable breeding, because specific elements of health, behaviour, and longevity can be improved and the quality of products can be adapted to consumer needs. Considerable investments in farm animal genomics at the European level will be necessary in order to stay competitive at the world level. This influence is needed to ensure European influence on the genetic make up of the future farm animals and access for European breeding industries to animal genome information for use in practical breeding. European breeding companies are mainly SMEs, and not able to undertake this huge effort on their own. Links with the human and plant genomic research and bio-informatics should be improved. Current national activities should be coordinated at the European level through networks, exchange of resources, combining databases, and data-warehousing. This ensures effective use of funds and the indispensable contacts with the breeding organisations and breeding populations in the home countries.

Introduction

Genomics has an enormous impact on the life sciences. Genome information from mouse and man becomes available at an ever increasing speed. In the present decade it will be possible to harvest in the European agrofood sector from the huge investments in fundamental genomics.

Europe traditionally has played an important role in the improvement of the major livestock species worldwide. Also, the impact of farm animal selection on farm animal production as a whole is high, because breeding response is cumulative, sustainable and can be disseminated throughout the production chain. The reproduction and selection of farm animals is a knowledge intensive sector based on research in reproduction, genetics, informatics and statistics. At the start of the 21st century, farm animal breeding is at a crossroads. Information on genes as well as phenotypes are being incorporated into selection schemes. However, genomics offers even more potential for the future.

Genomics can provide the tools to improve

- the competitiveness of farm animal production,
- sustainable agriculture (e.g. the finetuning between organism and environment; animal welfare and animal health),
- genetic diversity, and
- quality and safety of production (e.g. traceability).

The investment gap with the United States is huge. For farm animals, ambitious molecular programmes are under way in the United States of America, in Japan and more recently in China. Significant research in the field of animal genomics has been presented by private companies (e.g. at the recent PAG and ISAG meetings including Monsanto, Celera and Curagen-Roche). Considerable investments in farm animal genomics and the implementation of genomics into European farm animal breeding and reproduction will be essential in order to

- keep up with developments,
- maintain the leading competitive position in classical breeding,
- prevent the movement of the best scientists to other continents,
- ensure that European companies benefit from European research investments,
- ensure access to specific biological resources ("unigene" collections of ESTs, cDNAs, genomic clones, radiation hybrids) and the distribution of these biological materials within the European research and breeders' community, and
- what may even be more important, maintain the right to remain involved in the future breeding of animals.

The situation in farm animal genomics research in Europe

The global success of European breeding is partly due to the intensive relationships with the research institutes and universities in their home countries.

Although most of the development in genomics and functional genomics comes from the human field, considerable achievements have also already been made in farm animal research. In the last decade, an enormous improvement in molecular tools was made available to the European scientific community essential for analysing farm livestock genomes. The European farm animal projects have been a great stimulant for the creation of these collaborations. Examples are the BOVMAP, the PiGMaP, Salmap and ChickMap projects. At this moment, scientist try to go a step further, and fine-map chromosomal regions associated with traits of interest, and even identifying the causal mutations, e.g the RN gene in the pig controlling meat quality, and the first development of DNA chips. Nevertheless, a huge sequencing effort is still necessary, especially of ESTs. This research is so expensive that international funding, exchange and cooperation are indispensable to be able to compete with outside Europe.

Also, some industrial partners have begun to be involved in international research and development programmes, thus ensuring practical relevance of the research.

The application of genomics in farm animal breeding

A lot of animals and SMEs involved in the breeding chain

In contrast to plant breeding, in the breeding of ruminants (cattle, goats, sheep) and pigs, a large number of associated breeding units (in farms) are needed in order to disseminate new breeding material. Because they get a limited number of offspring per year - a cow gets one calf per year - the cows at the farms are the mothers of the future animals. They all represent a part of the breeding chain. Also in pigs, a large number of farms is involved in the dissemination of top breeding animals to the farmer who fattens the pigs. Therefore implementation of breeding research into practice needs this continuous relationship and finetuning through local breeders and the national breeding organisations. They are often SMEs, and operate in their native language.

Joining forces

However, the European breeding companies are not capable to make the step from basic and comparative genomics to application on their own. Being mainly SMEs, they do not have the knowledge and certainly not the facilities to get a full picture of the huge amount of information and to estimate their potential value for their breeding work. Currently, the evaluation of potentially valuable genes specifically for their own breeding programmes is a problem for breeding companies. Besides the investments needed, the lack of knowledge and technologies that are necessary for the implementation of genomics into animal breeding currently inhibits the application.

Genomics for breeding and genetic resources

The main applications of genomics in animal production will come along parentage identification, traceability of food/animals, marker assisted selection, and marker assisted introgression, and not from GMOs. Also in the preservation of genetic resources, genome information will be a very useful tool. Marker assisted selection will especially be attractive for characters that can only be measured late in life time or after slaughter (e.g. fertility, longevity), for traits with low heritability, characters that are difficult or too expensive to measure (e.g. disease resistance) or in the case of unfavourable correlation between traits (e.g. milk production – fertility). Marker assisted introgression, the introduction of a favourable gene into a commercial population, can be done more quickly, targeted, and cost-effectively if an important gene can be traced with markers precisely. The use of GMOs in animal production is economically not feasible and not accepted by society.

Breeders' and genetic resources' access to genome information

At this moment European breeders have a leading competitive position in classical breeding globally. In the USA, more and more animal sequences are coming under patent protection with many more expected to come, esp. for medical purposes in human and animals. E.g. Curagen is now sequencing all transcribed sequences in the pig genome and surely will protect them by patents. Those sequences might not be freely available for the breeding of animals anymore which can also even restrict the preservation of genetic resources. The access of European breeding companies and genetic resources to genome information to use this in their work will be crucial.

Research, infrastructures and implementation means needed

1. Research

The following developments in research in the human and other key genomes need to be implemented in the research in farm animals genetics:

- (a) Genomics and proteomics. Further sequencing in farm animals is necessary, as the amount of ESTs and cDNAs to make links with other genomes is still far too small. In the short term, good implementation of micro-array technology in farm animals will be a key feature, needed to identify genes, gene expression and gene function involved in complex traits in farm animals. In the medium term, a further implementation of new methods in functional genomics will be needed, that enable the identification of the function of proteins and their interactions with other proteins in the animal.
- (b) Comparative genomics, to identify regulatory elements and possible causative mutations. Comparative sequencing has already been shown to be a powerful method to identify regulatory elements within genes. Comparative sequencing between human and animals not only will benefit the animal research but will also be used for the identification of regulatory elements in genes within human research as well (e.g. the 'obese' genes).
- (c) Bio-informatics. A prerequisite for an efficient use of the data obtained by the methods described under (a) and (b), are the implementation of good bioinformatics tools and bioinformatics facilities.

Heterogeneity of databases. A problem that needs attention is the heterogeneity of databases: 1) different systems house the same types of information (e.g. genetic maps from different species) 2) different types of data need to be related and available for analysis through a single interface.

Data-warehousing by means of on-line analytical processing systems. As it will become possible to analyse more data with increasing detail, it is necessary to integrate data in order to provide a framework that breeders can use and understand. As this data integration can only take place inside the computer, more and more advances in scientific knowledge, as well as downstream products of breeding, will depend on geographically distributed groups of research specialists, that pool their efforts and knowledge in analysing biological information. Thus there is a need to provide *real-time data management to geographically distributed research collaborators* (Internet).

2. Networks of excellence

As research into genomics is complicated and expensive it demands international exchange and cooperation. Several countries have started to invest money in programmes aiming to develop systematic knowledge of the genomes in farm animal species (e.g. ASTEROGER in France, Agrofood Genomics Initiatief – landbouwhuisdieren

in the Netherlands, and similar programmes in the UK, Germany). Coordination of national and international efforts, and of government, industry and science will have to consider several aspects:

Genome and farm animal genome networks. The European laboratories and industries need to develop closer network relationships

- 1) with the human and plant genomes and bio-informatics.
- 2) between them. Special networks across countries for the major farm animals (cattle, pig, chicken, fish) are necessary to exchange and combine the knowledge and specific projects scattered over Europe.

By improving a limited number of centres which already have a leading role in this area of research a cost effective use of funds and a good interaction with the national breeding industries in the individual countries can be achieved. Good dissemination of the results, and easy access to commercial breeding material by the different research groups will be required.

Involvement of industry Farm animal breeding and reproduction organisations should be involved in the development and implementation in all stages to ensure that research results will really be used. Participation of breeding organisations in all projects will be of vital importance to ensure relevance and implementation of the research for Europe and assist in the technology transfer aspect that is of major importance.

3. Databases

The specific biological resources (“unigene” collections of ESTs/cDNAs, genomic clones, Radiation hybrids) and the distribution of these biological materials within the European research and breeding community (easy access to biological materials) must be developed further.

For the development of general bio-informatics tools institutes like the European Bio-Informatics Institute (EBI)/EBML can play a role, and databases specific for farm animals can be concentrated in one or a few centres specialised in farm animal genomics. Good links will be necessary to ensure the efficient comparison of human/mouse data with data obtained from animals and to keep up with new developments in these species, e.g. by means of a genetic and informatics specialists for further implementation of database linking software, enabling the utilisation of public database information for comparative mapping and the development of good integrated linkage maps for livestock.

4. Implementation

The efficient implementation of genomics data in existing breeding programmes will require the development of specialised breeding strategies and breeding programmes. The existing programmes based on quantitative genetics and phenotypic data need to be extended to integrated programmes describing ways to utilize molecular and phenotypic information in genetic evaluations.

The barriers that need to be taken are, next to comparative genomics, and tracing/getting access to the right databases:

- a) accessing and utilising the results of QTL experiments using farm animals,
- b) evaluation of promising candidate genes in breeding programmes,
- c) development of a new generation of programmes for breeding value estimation that adequately combine both phenotypic and genotypic information.

5. Reproduction

In farm animal breeding reproduction is a crucial phase. When it comes to genetic resources and farming, the possibilities to store, thaw and use genetic material are important. Therefore, research into semen, egg and embryo biology and technologies need to be developed further.

6. Small projects and small research groups

The research and networks must be open to small research groups and industries, e.g. from Southern Europe, so that scientists from all countries, small industries and minor species (e.g. sheep, goat, duck, ostrich) will be able to develop skills and new products. Special small scale projects must make it possible to 'hook on' to the major laboratories and industries.

Conclusions

In order to stay competitive at the world level, and to ensure European influence on the genetic make up of the future farm animals considerable investments in farm animal genomics at the European level will be necessary. Access of breeders and genetic resources to the use of genome information is a major concern which needs careful attention. Most European animal breeding companies are SMEs and hardly have the knowledge and certainly not the facilities to achieve this alone. Therefore, European wide efforts, and transfer of knowledge from the human and other key genomes are necessary. The emphasis should be on a) research and development of farm animal genomics and bioinformatics in networks of excellence comprising the current research centres of excellence and breeding industries in farm animals, b) transfer of the knowledge of key genomes to farm animals and improved links with key genome databases, c) coordination of national farm animal genomics efforts, and d) the involvement of farm animal reproduction and selection organisations in the development and implementation of this complex area.

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Farm Animal Industrial Platform (FAIP)

The Farm Animal Industrial Platform (FAIP) is an independent European forum for farm animal reproduction and selection organisations (both industry and farmer's cooperatives), including companies not involved in genetic improvement, reproduction and related technologies. In 1995, the major European breeding industries joined forces, because of their common interest in precompetitive research at European level.

Research in the area of farm animals has an impact beyond species. For this reason, the industries of a wide range of farm animals - cattle and other ruminants, pigs, poultry and aquaculture - are represented within FAIP, directly or through their umbrella organisations. The majority of companies active in this sector are SMEs.

The aim of the Platform with regard to breeding and reproduction of farm animals is:

- 1) to stimulate research and research funding at European level, and to indicate the direction of research that is important for the industry to the European Commission and other interested bodies,
- 2) to stimulate interaction and cooperation between researchers and industry involved in the reproduction and selection of farm animals
- 3) to be a focal point for basic information about European research funding and granted research projects
- 4) to be a forum for farm animal industry interested in and/or related to reproduction and selection.

The Platform has contacts with project holders of EU granted farm animal reproduction and selection projects. These contacts are important to avoid duplication of efforts, ensure relevance, and optimise use of European funds. FAIP informs members about funding possibilities at European level, and stimulates participation of industries in research projects through partnering of industry and scientists in international research projects.

FAIP is a forum for the development and expression of opinions on research related topics (e.g. patent directive and new breeding technologies) with regard to farm animal breeding and reproduction.

FAIP aims at explaining farm animal breeding and reproduction to a wider audience. Transparency and a continuous dialogue with society are vital for mutual understanding of animal breeding and reproduction and animal products.

Cattle and other ruminants

CIA Linalux, Ciney, Belgium
Federation of Danish A.I. Societies, Aarhus, Denmark
Finnish Animal Breeding Association (FABA), Vantaa, Finland
U.N.C.E.I.A. (Union of French A.I. Cooperatives), Paris, France
Arbeitsgemeinschaft Deutscher Tierzüchter, Bonn, Germany
Besamungsverein Neustadt ad Aisch e.V., Neustadt ad Aisch, Germany
The AI Cooperatives of Ireland, Enfield, Ireland
Laboratorio di Tecnologie della Riproduzione (CIZ), Cremona, Italy
Semenitaly S.r.l., Saliceta S.Giuliano Modena, Italy
Altapon, Garnwerd, The Netherlands
Holland Genetics V.O.F., Arnhem, The Netherlands
Dr. Van Haeringen Laboratorium B.V., Wageningen, The Netherlands
Intervet, Boxmeer, The Netherlands
GENO, Hamar, Norway
Svensk Avel, Skara, Sweden
Arbeitsgemeinschaft Schweizerischer Rinderzüchter, Zug, Switzerland
Genus, Newcastle upon Tyne, UK
Meat and Livestock Commission, Milton Keynes, UK

Fish

SYSAAF, Noirmoutier, France
Nutreco / Euribrid B.V., Boxmeer, The Netherlands
Dr. Van Haeringen Laboratorium B.V., Wageningen, The Netherlands
Intervet, Boxmeer, The Netherlands
Aquagen, Kyrksaeteröra, Norway

Pigs

Seghers Gentec, Buggenhout, Belgium
Federation of Danish Pig Producers and Slaughterhouses, Copenhagen, Denmark
Finnish Animal Breeding Association (FABA), Vantaa, Finland
U.N.C.E.I.A. (Union of French A.I. Cooperatives), Paris, France
France Hybrides, Saint Jean de Braye, France
Schaumann Besitz-Hülseberg GmbH & Co KG, Wahlstedt, Germany
Zentralverband der Deutschen Schweineproduktion e.V., Bonn, Germany
ANAS - Associazione Nazionale Allevatori Suini, Rome, Italy
Semenitaly S.r.l., Saliceta S.Giuliano Modena, Italy
IPG - Institute for Pig Genetics, Beuningen, The Netherlands
Nutreco / Euribrid B.V., Boxmeer, The Netherlands
Dr. Van Haeringen Laboratorium B.V., Wageningen, The Netherlands
Intervet, Boxmeer, The Netherlands
Cotswold, Rothwell, UK
PIC Group, Cambridge, UK
Meat and Livestock Commission, Milton Keynes, UK

Poultry

Scanbrid Int. A/S, Bjaeverskov, Denmark
Hubbard-ISA, Lyon, France
Lohmann Tierzucht, Cuxhaven, Germany
Nutreco / Euribrid B.V., Boxmeer, The Netherlands
Hendrix Poultry Breeders, Ospel, The Netherlands
Dr. Van Haeringen Laboratorium B.V., Wageningen, The Netherlands
Intervet, Boxmeer, The Netherlands
Association of British Primary Breeders & Exporters, UK
BUT - British United Turkeys, Broughton, UK
Ross Breeders, Midlothian, UK